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Using SNOMED CT Expression Constraints to Bridge the Gap Between Clinical Decision-Support Systems and Electronic Health Records

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Abstract. Clinical decision-support systems (CDSSs) should be able to interact with the electronic health record (EHR) to obtain the patient data they require. A recent solution for the interoperability of CDSSs and EHR systems consists in the use of a mediated schema which provides a unified view of their two schemas. The use of such a mediated schema requires the definition of a mapping between this schema and the EHR one. In this paper we investigate the use of the SNOMED CT Expression Constraint Language to characterize these mappings.

Keywords. Clinical decision support systems, Electronic health records, SNOMED CT, interoperability

1. Introduction

A clinical decision-support system (CDSS) can be defined as "any computer program designed to help health professionals make clinical decision" [1]. A typical example are decision-making tools to assist clinicians by providing patient-specific recommendations based on clinical guidelines. Ideally, CDSSs should operate based on the patient data contained in the electronic health record (EHR), without having to manually re-enter the data that are already in the system. An important problem is the so-called "impedance mismatch" between the CDSS and the EHR. This means that the CDSS often uses rather abstract concepts, i.e. it requires data at a level of abstraction much higher than the raw data available in the EHR. Another problem is that the terminologies used in the CDSS and the EHR may differ.

Several works have proposed the use of a mediated schema which provides a reconciled and integrated view of the CDSS and EHR schemas [2][3]. When the CDSS needs to evaluate a clinical statement with concrete patient data, it submits a query in terms of the mediated schema instead of the EHR one. To do this, a mapping must be established between the mediated and the EHR schemas. This mapping may benefit from a precise characterization of the abstract concept in terms of standardized clinical terms.

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In the past we used OWL expressions based on SNOMED CT terms for this purpose [3]. Here, our goal is to evaluate the use of the SNOMED CT Expression Constraint Language [4] as a means of describing complex and/or abstract concepts that can be found in CDSSs. To do this, we have performed a case study based on the concepts of a computer-interpretable guideline (CIG) for the management of chronic heart failure [5]. Note that either of the above characterizations are of interest by themselves, regardless of the EHR standard architecture underlying the mediated schema.

2. Material and Methods

2.1. SNOMED CT Expression Constraint Language

SNOMED CT is considered the most comprehensive multilingual clinical healthcare terminology in the world [5]. The definition of complex/abstract concepts that we aim for can be often performed via enumeration of SNOMED CT terms, i.e. in an extensional way. However, this approach may be unpractical, e.g. in cases where a large number of terms are involved. In contrast, the SNOMED CT Expression Constraint Language [4] enables the intensional definition of a subset of SNOMED CT terms. In our case, SNOMED CT Expression Constraints (ECs) can be employed as an intensional definition of complex/abstract concepts which can be represented as a subset of concepts. Therefore, they can be used as an alternative to the extensional enumeration of SNOMED CT terms, or in case an adequate set of terms cannot be readily identified.

Roughly, a SNOMED CT EC requires choosing a subset of SNOMED CT concepts and, optionally, refines it by means of attributes and values for such attributes. More formally, a SNOMED CT EC contains either a single concept or a series of concepts joined by conjunction (`AND`) or disjunction (`OR`) operators. Each concept in the EC is normally preceded by a constraint operator. Constraint operators include: descendantOf (`<`), descendantOrSelfOf (`<<`), ancestorOf (`>`), ancestorOrSelfOf (`>>`), memberOf (`^`), and memberOfClosure (`^*`). An EC may also contain a refinement, which consists of grouped and/or ungrouped attributes. Each attribute comprises the attribute name and the value for the attribute. The attribute could be optionally preceded by some cardinality and/or the reverse flag (`R`). Attribute values can be either a concrete value or an EC. The conjunction and disjunction operators can be applied to concepts, ECs, refinements, attributes and attribute groups. The exclusion operator (`MINUS`), similar to mathematical subtraction, can be used in simple expressions and in attribute values.

2.2. A guideline for chronic heart failure

In this work we have conducted a case study using the clinical concepts within a CIG for the management of chronic heart failure (CHF). Concretely, we have worked with the clinical guideline for the diagnosis and treatment of CHF developed by the European Society of Cardiology. The guideline was previously modelled in the PROforma CIG language, as part of a project for the development of an electronic care plan for the treatment of comorbidities. This PROforma model has a significant level of complexity, due to the intrinsic complexity of the pharmacological treatment of CHF. In our case study we have focussed on the points of the PROforma model where some interaction with the EHR occurs, either for retrieving existing patient data (e.g. lab test results, etc.) or for adding new data (e.g. physician orders, etc.). In a previous work we identified these points, which exactly correspond to the complex/abstract concepts that the clinical guideline requires to support CHF management [7]. We initially identified 33 concepts in total in the PROforma model. When conducting this study, we observed that some of the concepts were artificially grouping several other concepts. After performing the necessary adjustments, the final number of concepts was 47.

2.3. Description of guideline concepts as SNOMED CT expression constraints

Two modellers independently addressed the manual description of the above concepts as SNOMED CT ECs. The IHTSDO SNOMED CT Browser [8] and the SNQuery execution engine for SNOMED CT ECs [9] were used as tools in this process. The modellers tackled the problem with two different approaches. In the first approach (without refinement) the modellers try to describe the concepts using rather simple ECs, based on precoordinated SNOMED CT terms and set theory operators (AND, OR and/or MINUS). To do this, they first look for the relevant concept (or concepts) using the search tool of the IHTSDO browser. Then, they filter the results considering the semantic tag of the CIG concept (finding, disorder, etc.). After that, they select the best match (or matches) and examine the available details. Finally, they devise an EC describing the given concept and check its appropriateness by executing it in the SNQuery engine and analysing the results. In the second approach (with refinement), the modellers start with a more complex EC aiming to capture the CIG concept, and then execute it in the SNQuery engine. After that, the query results are analysed and the EC is refined until it corresponds to the intended meaning. Notice that both approaches can be interleaved so that they can mutually benefit from the clues obtained by the other.

3. Results

Table 1 shows a representative sample of the 47 concepts we have analysed in our case study. According to the SNOMED CT semantic categories, we identified 11 concepts corresponding to disorders, 10 corresponding to findings, 21 representing procedures. We also identified several situations and regimes/therapies, in a less significant number. In this section we report on the most significant results of our case study.

In the case of disorders, both modellers found all the concepts as ECs using the approach without refinement. Regarding findings from measurement or imaging procedures (see concepts #3.1, #3.2, #3.3 in Table 1), the important issue is to differentiate between abnormal and normal findings. The modellers have used different approaches in some of the cases. For example, in the case of X-ray_results (see concept #3.2), the approach without refinement yielded a more faithful expression than the one with refinement. However, in the case of BNP_results, since the modellers were not able to find any precoordinated term for the results of BNP[2] measurement, an EC with refinement was proposed (which yields no results when it is executed).

Procedures that represent medical exams (e.g. see concept #5) usually can be found as precoordinated terms and hence the approach without refinement is feasible. However, in general the concepts related to the administration of drugs (also procedures) were harder to find as precoordinated terms, hampering the approach without refinement. In this particular case, the use of the SNQuery engine has proven very valuable, by

[2] BNP stands for brain natriuretic peptide.

executing ECs like the following one, which returns the set of substances that take part in the relationship *Direct substance* of all *Administration of substance* procedures:
< 105590001 |substance|: R 363701004 |Direct substance | = <<432102000 | Administration of substance |

Then, for each substance of interest, if such substance was a result of the above expression, we have executed an expression like the following one to confirm (or discard) if there is any precoordinated term for the concept:
<< 432102000 | Administration of substance |: 363701004 |Direct substance | = << 373254001 | beta-Blocking agent |

Using this method, one of the modellers was able to find an EC for beta-blockers administration (see concept #7). Despite of the considerable amount of precoordinated terms for the administration of substances, the majority of CIG concepts corresponding to medications must be modelled as postcoordinated expressions (see e.g. concept #8).

Table 1. CIG concepts with a description in SNOMED CT EC Language. If applicable, ECs without (w/o ref.) and with (w/ ref.) refinement are given. The type of concept is: disorder (D), finding (F) or procedure (P).

<table>
<tr><th>CIG Concept</th><th>#</th><th>Type</th><th>Expression</th></tr>
<tr><td>angioedema</td><td>1</td><td>D</td><td>w/o ref.: <<41291007 |Angioedema|</td></tr>
<tr><td>cough</td><td>2</td><td>F</td><td>w/o ref.: <<49727002 |Cough|</td></tr>
<tr><td>ECG_etc_results</td><td>3.1</td><td>F</td><td>w/o ref.: <<102592004 |ECG|</td></tr>
<tr><td>X-ray_results</td><td>3.2</td><td>F</td><td>w/o ref.: << 168733007 | Standard chest X-ray normal (finding) | OR << 168734001 | Standard chest X-ray abnormal (finding) |
w/ ref.: << 404684003 |finding|: 363714003 |Interprets| = (<< 168537006 | Plain radiography |: 405813007 |Procedure site| = ((<< 51185008 | Thoracic structure | MINUS 76752008 | Breast structure |) MINUS 39607008 | Lung structure |))</td></tr>
<tr><td>BNP_results</td><td>3.3</td><td></td><td>w/ ref.: <<118245000 | Measurement finding |: {363713009 |Has interpretation | = (17621005 |Normal| OR 263654008 | Abnormal|), 363714003 |Interprets | = 390917008 | Brain natriuretic peptide measurement |}</td></tr>
<tr><td>ACEI_intolerant</td><td>4</td><td>D</td><td>w/o ref.: << 293500009 | Angiotensin-converting-enzyme inhibitor adverse reaction|</td></tr>
<tr><td>echocardio_action</td><td>5</td><td>F</td><td>w/o ref.: <<40701008 | Echocardiography | MINUS ((<< 433235006 | Fetal echocardiography |) OR 431852008 | Pediatric echocardiography |)</td></tr>
<tr><td>betaclocker_action</td><td>7</td><td>P</td><td>w/o ref.: <<439630003 | Beta adrenergic receptor blocking agent therapy | MINUS <<315052006 | Beta blocker prophylaxis |
w/ ref.: << 18629005 | Administration of drug or medicament |: 363701004 | Direct substance| = << 373254001 |beta-Blocking agent|</td></tr>
<tr><td>diuretics_action</td><td>8</td><td>P</td><td>w/ ref.: << 18629005 | Administration of drug or medicament |: 363701004 | Direct substance | = << 372695000 | Diuretic |</td></tr>
</table>

Among the operators of the SNOMED CT Expression Constraint Language, we have mainly used the constraint operators descendantOf and descendantOrSelfOf, applied to both concepts and attribute values, as well as the conjunction, disjunction and exclusion operators on simple expressions and/or attributes. Other constraint operators, reverse attributes and cardinality operators have not been used in the concept definitions.

4. Conclusions

In conclusion, our case study has served to demonstrate that the SNOMED CT Expression Constraint Language can be used to describe the clinical concepts in a real-world CIG to a reasonable extent. Roughly speaking, about 75% of the concepts could be successfully described with ECs without refinement. Among the remaining concepts, the modellers were able to propose ECs with refinement in all cases except one. However, the vast majority of these ECs yielded no result, which suggests that those concepts would require a definition based on postcoordination

Concerning the use of the SNOMED CT Expression Constraint Language for purpose of describing complex and/or abstract concepts in CIGs, our assessment is positive. However, in hard cases (e.g. highly specific concepts) the use of ECs does not seem to solve the problems associated to the direct search (i.e. non intensional) of adequate SNOMED CT terms. The main benefit of the use of ECs lies in the possibility of executing them using appropriate tools, such as the SNQuery engine. For a proper comparison with the characterization alternatives we have used so far, a further in-depth evaluation will be required.

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[8] IHTSDO SNOMED CT Browser, © IHTSDO 2016 v1.32, http://browser.ihtsdotools.org

[9] SNQuery SNOMED CT Expression Constraint Execution Engine, IBIME – ITACA, Polytechnic University of Valencia, VeraTech for Health, http://diebosto2.pc.upv.es:8888/SnomedQuery/